Biotechnology for Materials Synthesis and Destruction

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Biotechnology provides the capability to synthesize desirable materials and to biodegrade unwanted materials. Coatings, fuels, propellants, deicers, pharmaceuticals, dyes, polymers and adhesives can be both produced and degraded by biological systems.

Sustainable development has pushed the chemical industry to find less expensive, less energy-intensive, and environmentally cleaner synthetic processes (often called "green chemistry"). One successful approach for synthesis of industrial, pharmaceutical, and agricultural chemicals involves **biocatalysis, the use of living cells or enzymes as catalysts** for chemical reactions. Biocatalysis replaces the harsh conditions and undesired byproducts of classical chemical synthesis with the focused production of specific compounds under the mild conditions required to support biological processes.

Biocatalytic processes for commercial applications have been the focus of intense research by the chemical industry. The applications range from the development of microbial processes for specialty and commodity chemicals such as indigo, to the use of bacterial proteins as biochips in future microprocessors. The Air Force Office of Scientific Research (AFOSR) has supported research in biocatalysis with grants to industry. For example, 3M developed a process for the bacterial production of intermediates for the synthesis of 3-hydroxyphenylacetylene, an expensive material used to produce high-temperature polymers and adhesives.

Biocatalytic processes are employed in the commercial production of many compounds:

- Polyphenylene polymers
- Acrylamide
- Xanthan
- Vitamin B12
- Detergent lipases
- Dyes
- Aspartame
- Phenoxy propionate herbicides
- Variety of antibiotics and hormones

Biocatalysis is commonly used in the production of chiral compounds by the pharmaceutical industry. Often, only a single enantiomer of a chiral compound has therapeutic value. Chemical syntheses of chiral compounds typically yield mixtures of enantiomers difficult and expensive to separate. In contrast, enzymatic processes often produce a single enantiomer in huge excess, eliminating the requirement for expensive separation processes.

Novel enzymes and the products they form are constantly being sought by pharmaceutical, industrial, and agricultural companies. The search has revealed new enzymes in plants, animals, bacteria, fungi, and algae from a variety of habitats including the extreme environments of hot springs and deep-ocean thermal vents. Some of the enzymes catalyze transformations of a variety of compounds, making them potentially useful in the synthesis of commercially valuable products.

The microbial processes and physiology involved in biodegradation of organic chemicals have been the focus of considerable research over the past 25 years. The result has been an explosion of information on bacterial and fungal degradative pathways, enzymes, and molecular biology. This new knowledge has led to the use of enzymes and microbial cells as biocatalysts in the synthesis of specialty compounds.

Scientists at AFRL/MLQ have played a key role in recent advances in the discovery and application of microbial processes involved in biodegradation of synthetic organic materials. AFRL/MLQ researchers are particularly well-qualified to develop novel applications of microbial enzymatic reactions to synthetic processes. Many novel organisms and enzymes have broad substrate specificities and properties that make them excellent biocatalysts in synthetic processes. Some of the reactions are well established and are already being applied in industrial syntheses. One example is the aromatic hydroxylation of benzene by a *Pseudomonas putida* strain to synthesize 1,2-dihydroxy-3,5-cyclohexadiene for the production of polyphenylenes. Another example is the hydrolysis of acrylonitrile to acrylamide by the nitrile hydratase from *Rhodococcus rhodochrous*. Enzymes able to catalyze both the biosynthesis and biodegradation of polyurethanes have been discovered, and the industrial potential of other recently discovered reactions has yet to be realized.

Potential application of biocatalysis is not limited to the organisms and reactions known today. The leadership position of AFRL/MLQ researchers in the field of biodegradation makes them exceptionally qualified to discover and develop new organisms and enzymes with the capacity to catalyze desired reactions. AFRL/MLQ scientists, under an AFOSR-sponsored program, collaborate extensively with Prof. David Gibson at the University of Iowa Center for Biocatalysis. Prof. Gibson discovered the dioxygenase enzymes that attack aromatic compounds; he has played a key role in the elucidation of their structure and function.

Facilities at AFRL/MLQ include a state-of-the-art biotechnology lab staffed by biochemists, microbiologists, and molecular biologists.

Point of Contact

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